# Integrated Control Electronics for Adjustable X-ray Optics

PI: Susan Trolier-McKinstry, Penn State University
Co-I: Thomas N. Jackson, David N. Burrows, Derek Wilke, Penn State;
Paul B. Reid and Daniel A. Schwartz, Smithsonian Astrophysical Observatory

The goal of the proposed program is to enable increased angular resolution and collection areas for future major X-ray observatories by incorporating improved figure control of the mirror surfaces. In particular, this project will develop thin film transistor-based control electronics on thin film piezoelectric actuators. We will integrate ZnO transistors on piezoelectric actuators to enable large-scale adjustable X-ray optics with subarcsecond image quality. The incorporation of electronics directly on the piezoelectric material will enable simplified control of individual piezo cells and increase system fault tolerance, significantly reducing system complexity and greatly enhancing the feasibility of adjustable X-ray optics.

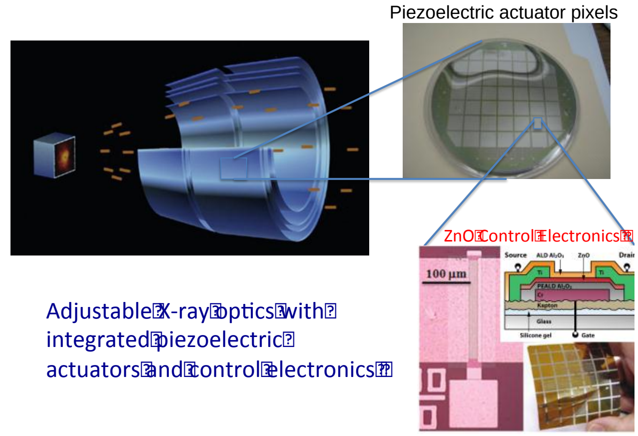


**Fig. 1: Grazing incidence optics with piezoelectric actuation and integrated control electronics**

We propose a scalable, adjustable optics solution for future high resolution, large collecting area X-ray telescopes, in which pixelated piezoelectric films are deposited on the backs of mirror elements, and are used to apply stresses to the mirrors that force them into the required surface figure. This technique enables the use of thin, light-weight optical elements to achieve sub-arcsec angular resolution. We have demonstrated deposition of high-quality $PbZr_{0.52}Ti_{0.48}O_3$ (PZT) piezoelectric films on thin glass substrates and produced electrically-induced deflections that would enable 0.5 arcsec angular resolution on very large X-ray telescopes.

As the sizes of the mirrors are scaled up, the number of electrical connections required for full control of the mirror surfaces increases commensurately. At present, one contact to each top electrode is needed for each cell, along with a single contact to the bottom electrode. For example, a 40 x 40 array of cells requires 1,601 electrical contacts for 1,600 cells. To reduce the complexity of the control system, we will implement a row-column address scheme similar to that used for flat-screen computer monitors. In this case, the number of electrical connections can be reduced to 81 for a $40 \times 40$ array, which would significantly simplify the control circuitry. This simplification will be achieved using thin film ZnO transistors on top of, or adjacent to, each piezoelectric element. The ZnO devices will serve as switches that control the voltages applied to the piezoelectric elements. This adds a means of providing redundancy, as well as isolation of cells that fail over the course of use. In addition, a control scheme for the adaptive optics system will be developed.

The integration of ZnO electronics with piezoelectrics has the potential to revolutionize the way in which piezoelectric microelectromechanical systems, including those for X-ray optics, are controlled. It promises to be a transformative breakthrough in grazing incidence optical systems. Moreover, if successful, this approach can be applied to all manner of thin adjustable optics, including but not limited to reflective non-grazing incidence visible, IR, and UV systems, greatly simplifying command and control and increasing fault tolerance.